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Conservation in the context of wildflower harvesting: The development and implementation of a Vulnerability Index on the Agulhas Plain of South Africa

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Abstract

This paper focuses upon the role that science-based interventions allied to effective regulatory regimes can play in reducing the threat posed by inappropriate harvesting of wild flora. A Vulnerability Index (VI) has been developed for 150 natural *fynbos* species that exist on South Africa's Agulhas Plain, where intense wildflower harvesting occurs. The methodology underpinning the generation of the VI is outlined and justified in this paper. The VI comprises a range of characteristics relating to species distribution and biology that are likely to influence vulnerability to harvesting. The VI is proving to be an important tool for regulating the harvesting of wild *fynbos* and maintaining the resilience of natural ecosystems threatened by climate change. Furthermore, economic development and livelihood stability are promoted by protecting the resource base of marketable species. The paper discusses issues that have arisen relating to the application and rollout of the VI in practice.

Key words: Cape Floristic Region, *fynbos*, sustainable harvesting, biodiversity conservation, Red List

Introduction

South Africa hosts the Cape Floristic Region (CFR), which is one of the most species-rich and botanically diverse regions in the world. The CFR encompasses a land area of some 90 760 km2 (less than 4% of the southern African subcontinent) and an estimated 9 383 species of vascular plants, of which just over 68% are endemic (Manning and Goldblatt 2012). However, the biodiversity of the CFR is under pressure on many fronts including anthropogenic land use changes and climatic change (Raimondo et al. 2009). Conserving the region's rich biodiversity has been identified as a priority enshrined in various policy documents (GSA, 2005) not least due to the critical role the landscape plays in terms of job creation and ecosystem services. This paper focuses specifically upon the role that science-based interventions can play in reducing the threat posed to the indigenous *fynbos* biome by inappropriate harvesting of wild flowers. Wildflower harvesting generates socio-economic benefits and also provides an economic case for maintaining the wildflower resource base within natural environments. However, regulation and oversight are required to ensure that wildflower harvesting practices do not contribute to local extinctions of population or individual species and result in broader ecosystem disruption.

Pioneering work has been undertaken by a team of botanists, who have developed a Vulnerability Index for natural *fynbos* populations that exist on South Africa's Agulhas Plain (Privett and Gaertner 2012). The Agulhas Plain provides a microcosm of the issues facing conservation, agricultural development and sustainable utilization within the broader CFR (Privett et al. 2002). The Vulnerability Index has subsequently been used to guide regulatory and conservation agencies in the fulfilment of their duties, for example in making decisions regarding the award of harvesting permits. The methodology underpinning the generation of this Vulnerability Index is outlined and justified in this paper. The paper begins by setting the ecological, economic and institutional context from which the Vulnerability Index emerged. Then the methodology underpinning the Index is described and justified. The paper concludes with a discussion of the experiences of conservation agencies in implementing the Vulnerability Index in practice. Recommendations are made for further research and policy work that will enable the complete benefits of the Vulnerability Index to become fully embedded in conservation practice in South Africa and in other global environments where humans harvest natural products from the wild.

Wildflower Harvesting within the Cape Floristic Region

The Cape Floristic Region (CFR) enjoys iconic status among South Africa's natural riches, being home to 9383 plant species, of which 68 per cent are endemic (Manning and Goldblatt, 2012:29). The region's global botanical importance is recognised in its designation as a World Heritage Site and an IUCN world centre of plant diversity (CapeNature 2016, Rebelo, 1995). The main biome is known locally as *fynbos* ('fine-leaved bush'), however one third of the original area of *fynbos* has been lost, 3343 species are of conservation concern and 1839 species are threatened (SANBI, 2017). Indeed, the CFR is one of most threatened reservoirs of plant and animal life on earth (UNDP, 2003) The main threats to the natural *fynbos* include land conversion for agriculture, infestation by alien plant species, and the impacts of climate change (Bek et al. 2017). Poor harvesting practices increase the threat to locally endemic, rare or already threatened species (Binns, et al. 2001; Heydenrych, 1999; Turpie, 2004; Laubscher et al. 2009).

The 270,000 hectare Agulhas Plain is located in the southernmost region of the CFR and is recognised for its biodiversity and vulnerability (see Figure 1). Nearly 2000 plant species exist in the region, of which 100 are locally endemic and unique (Cowling and Holmes, 1992). One hundred and twelve species are on the SANBI Red List and many are on the verge of extinction (SANBI, 2017). The biodiversity importance of the region is further illustrated by the fact that it contains 36 different vegetation types, twelve wetland types and two sites designated as having international significance by the Ramsar Convention (Child, 2010; Treurnicht, 2010).

[Insert Figure 1 near here)

Commercial wildflower harvesting has taken place in the CFR for over a century, with both fresh and dry stems being sold into domestic and international markets (Cowling and Richardson 1995). These wild floral products are harvested not only for their flowers, but also f for their cone-like structures. Whilst others are harvested as foliage, thus for their leaf quality, and their colour characteristics. In recent years the industry has evolved significantly with *fynbos* bouquets being stocked in greater volumes by South African retailers, whilst the global bouquet market has expanded rapidly (CapeFloraSA, 2016; Bek and O'Grady 2018). During 2015, approximately one million bouquets were exported, comprising a mix of focal flowers, such as *Proteas* and *Leucospermums* which are often cultivated, and wild harvested greens, such as *Berzelia lanuginosa*, (CapeFloraSA, 2016). Department of Trade and Industry (DTI) export data suggests that *fynbos* exports in the twelve months to July 2016 were valued at around R300,000 million (US$16M) (DTI-RSA, 2016), whilst industry data suggest that 36 million stems of wild and cultivated fynbos stems were exported in the twelve months to March 2017 (Bek and O'Grady 2018). The wildflower industry is an important contributor to the Western Cape economy, providing employment for around 3000 people many of whom reside in remote rural areas. However, these economic gains are often at odds with conservation objectives due to the increasing pressure imposed upon the natural *fynbos* resource base. CapeNature's (the provincial conservation agency) licensing system plays an important role in regulating what species can be utilised in wild flower harvesting.

Formal regulation was introduced in 1938 when a harvesting permit system was initiated to protect vulnerable species (Davis, 1992). Harvesters, landowners, packsheds and sellers require annual licences awarded by CapeNature in order to pick, process or sell specific species. Species whose conservation status is considered to be too precarious may not be picked, whilst others may only be picked in specific locations where they are relatively abundant (Bek and O'Grady 2018). In recent years, the conservation status of species has been determined by reference to the South African National Botanical Institute's (SANBI) 'Red List' of threatened plant species, which includes all *fynbos* species (SANBI, 2017). The Red List states the conservation status of plant species and draws attention to the degree to which individual species are under threat within the country as a whole (Raimondo et al. 2009). Figure 2 below illustrates the grading used within the Red List Categories (Raimondo et al. 2009). In order to differentiate between the levels of threat faced by individual threatened species, assessments are carried out using five quantitative criteria, which focus upon population characteristics including size, range, and rate of change (see Figure 3 below). In 2007, pioneering work was undertaken to build on the use of the Red List to better assess the vulnerability of species targeted for wild harvesting using the Agulhas Plain as a test area. This work was undertaken as part of the Sustainable Harvesting Programme which emerged as a core component of the Agulhas Biodiversity Initiative (Privett et al. 2002).

[Insert Figure 2 near here]

[Insert Figure 3 near here]

The Sustainable Harvesting Programme

In 2003, under the auspices of the Agulhas Biodiversity Initiative, The Flower Valley Conservation Trust (FVCT) was contracted to develop a pilot project which would demonstrate that harvesting wild *fynbos* is a viable land use option for the Agulhas Plain, 'that meets ecological, social and ethical standards of good practice' (FVCT, 2012). During the pilot programme the FVCT developed a multi-faceted Sustainable Harvesting Programme (SHP) whose components included practical harvesting guidelines (Van Deventer et al, 2015), worker training and a research programme focusing upon *fynbos* ecology (Privett et al, 2002; Bek et al, 2013; Bek et al, 2016). The pilot involved eight suppliers based in the Stanford-Napier-Gansbaai rural area of the Agulhas Plain, who were required to attain sustainable harvesting accreditation for their picking teams.

During the development of the Sustainable Harvesting Programme it was decided that more geographically specific guidance on the awarding of permits was required, as under certain circumstances some species are more vulnerable at a local level than they are nationally. Such species might therefore be particularly at risk if they are harvested. Therefore, a team of botanists was commissioned to develop an assessment method and Vulnerability Index for 150 harvestable species (71 that are harvested and 79 with the potential to be harvested) that exist in natural populations on the Agulhas Plain, the region within which the SHP was being piloted (Child, 2010).

The Vulnerability Index differs from the Red List in two significant ways: (i) it focuses specifically on the risks posed by harvesting; and (ii) it focuses only on natural species populations found on the Agulhas Plain. The Vulnerability Index is used in conjunction with the Red List by regulatory authorities, such as CapeNature, when assessing harvesting licence applications on the Agulhas Plain. The index provides an indication of how vulnerable each species is to being harvested, based on biological and geographical attributes. This was done by classifying and scoring species according to various easily observed biological characteristics that are likely to influence the response of *fynbos* species to harvesting. Summing the scores produces an index value – the higher the value the more vulnerable a species is to being harvested. Specifically, a high score indicates that even relatively low levels of harvesting are likely to deplete the resource faster than it can recover, resulting in a high likelihood of local extinction if the plant is harvested. It is recommended that harvesting is banned altogether for species with very high scores, whilst species with medium-to-high scores are designated for close monitoring. Such monitoring includes a periodic assessment (every three years) to determine the level of harvesting pressure on a species in relation to its known population levels. Research must be triggered when harvest pressure is high, and the results of research must further drive a review of species vulnerability listing which informs the licensing authority's qualifying permit protocols before awarding permits.

The Vulnerability Index is therefore seen as an important tool for regulating the harvesting of wild *fynbos* and contributing to conservation (Privett and Gaertner 2012). The principal objective of this paper is to outline the methodology underpinning the Vulnerability Index and to justify the choice of criteria and weightings which comprise the index.

Methodology

A recent study of the Agulhas Plain flora has determined that there are 2489 recorded indigenous plant species on the Agulhas Plain (Privett 2018). In determining which species to include in the Vulnerability Index we first included the seventy-one species recorded as being harvested from natural populations on the Agulhas Plain (Heydenrych 1999). It is estimated that this is probably closer to 100 as there are problems with species identification and a tendency for physically similar species to be put into broad groups such as 'Erica pink'. It was decided to add a further 79 species to include rare and endangered species, and species with harvesting potential.

In developing the Vulnerability Index, certain important assumptions were made relating to harvesting practices within its environmental context:

- Populations are only exposed to natural, ecologically acceptable fire regimes. Intervals should be at least ten years apart, with fires occurring between December and April (the natural fire season for the region)
- It is assumed that natural and functioning ecosystems prevail in harvested areas
- Precautionary harvesting levels prevail for harvesting not to exceed 50% of the foliage or flowers
- Only adult plants (older than 5 years), or plants that have flowered for at least two consecutive seasons, are harvested.

If one or more of the above factors does not apply, then the species will be at a greater risk than indicated by the Vulnerability Index score.

There are a number of characteristics relating to species distribution and biology that are likely to influence their vulnerability to harvesting. After careful deliberation, eight specific characteristics were selected to comprise the Vulnerability Index. These were deemed to be the most influential factors contributing to species resilience to harvesting. In addition, the data available for each of these eight characteristics was sufficiently robust to produce meaningful results. In some cases, estimates have been made based on the assessment of available information on the species, expert opinion and consultation with herbarium records.

Categorization and scoring of characteristics in the Vulnerability Index

This section outlines each of the eight characteristics which comprise the Vulnerability Index. The selection of each botanical category is justified and the ways in which scores are attributed are outlined. Categorization of several of these eight categories is based on a subjective division of a continuous variable, for example, decisions had to be made as to the dividing line between a ‘Widespread’ and ‘Restricted’ Geographic Range. The number in brackets after the description of each category below is the score allocated to a species fitting that profile. By adding these numbers together one arrives at the Vulnerability Index score for each species between 1 and 11. The higher the number then the more vulnerable that species is, in other words there is a greater risk that harvesting will affect the survival of that species. Based on the outcome, a cut-off level is determined for the index, and any species that score higher than this level are then recommended to be afforded some form of special protection. Thus, species with a score of 9, 10 or 11 are considered to be ‘no go’ species which should not be picked because harvesting poses too great a risk to their survival. Other species that attain lower scores can be regarded as more acceptable for flower harvesting, although those with scores of 7 and 8 should be prioritized for close monitoring.

1. Geographic range

The natural geographical distribution of a species is a key indicator of its vulnerability. Species which are found in multiple, widespread areas are more resilient than those contained within single, localized habitats. Species which are confined to a very restricted range are considered to be at considerable risk, hence the awarding of a score of 3 for species in this category. For example, the local endemic. Geographic range vulnerability scores have been calculated based primarily on Goldblatt and Manning’s research, as well as our local knowledge of the species (Goldblatt and Manning, 2000).

1. Widespread – occurring on the Agulhas Plain and in other areas within the CFR (0)
2. Restricted – endemic to the Agulhas Plain, found on area less than 500 km^2 (2)
3. Very restricted – localised and rare habitats within the Agulhas Plain found on an area that totals less than 100 km^2 (3)

2. Abundance and Area of Occupancy

Abundant natural and dense populations which spread across a wide area are considerably more resilient than localized, smaller populations. Rare species which are only found in small areas are at high risk, as single acts or events can have considerable impacts upon the status of the entire species. Vulnerability scores for each species have been calculated based upon expert knowledge of population sizes and/or geographic range:

1. Common – generalist species that occur in dense populations throughout most of their range (larger than 500 km^2) (0)

2. Localised – occurring in small or scattered populations in most of their range (<500 km^2) (2)
3. Rare – species restricted to a few scattered populations (<40 km^2) (3)

3. Regeneration

There are number of categories of regeneration into which *fynbos* plants can be divided. One of the most important characteristics from a harvesting perspective is the way in which a species regenerates after fire. Species with persistent rootstocks that re-sprout after fire tend to be very resilient to physical damage to the adult plant. Thus, these species are usually able to re-sprout even after repeated, heavy pruning associated with harvesting (Privett et al. 2014). However, recruitment from seedlings in such species is usually low (Marais 2012), and excessive damage as a result of heavy pruning or too-frequent fires can lead to reduced seed production and even mortality of adults. This will have a considerable impact on local populations and should be avoided.

Conversely, species dependent on seed for regeneration after fire are more likely to be killed by harvesting, especially young plants. Not only is seed removed by harvesting, but also the foliage (and subsequent flowering buds) is often unable to regrow, especially after heavy pruning:

1. Sprouters– regenerating from seed and by sprouting (including epicormic and rootstock re-sprouters) (0)

2. Seeders- regenerating only from seed (2)

3. Architecture

The architecture of the plant is very important when considering the impacts of harvesting branches. Species that have many branches are less likely to be impacted by harvesting than those species that have few branches. Current recommendations are that at least 50% of the foliage from each year’s crop should be left on each plant (Mustart and Cowling 1992, Maze and Bond 1996, Privett et al. 2014). However, removal of half the foliage from a plant with only two branches will place the plant at greater risk than the removal of half the branches from a multi-branched bush. As re-sprouters are very resilient to harvesting and able to re-sprout continuously, only seeding species have been included in the two architectural categories below:

1. Many branches, (5 or more branches growing off the main stem) (0)
2. Few branches, (4 or less branches off the main stem) (1)

4. Age to flowering

Species differ in terms of how old they are when they first reproduce. Some species flower and set seed in the first or second year after fire, while others may take over five years before they produce seed. Since wild fires are a common phenomenon on the Agulhas Plain, species that take longer than five years to set seed are vulnerable to becoming locally extinct following too frequent fires. Therefore, species are also vulnerable to harvesting which occurs before seed reserves have been given time to accumulate:

1. Flowers produced in 0-5 years (0)
2. Flowers produced in more than 5 years (1)

5. Soil seed bank

Some species store seed within the soil, as parent plants release seed on an annual basis. The regeneration of the majority of species with soil-stored seed is dependent on fire. In species that store their seed in the soil, harvesting of flowering stems results in the loss of some of this soil-stored seed reserve. The lifespan of these buried seed-stores (or soil banks) is important for determining the possible effects of harvesting. If most seed survives for less than one year, then intense harvesting which severely reduces seed production would leave little seed for regeneration should a fire occur during the year following the harvest. However, species with long-lived seed banks, with most seeds surviving several years, will be far more resilient to harvesting. Accurate information about seed longevity is not readily available, and the proposed categorization will require revision as further research information becomes available:

1. large – species relies on long lasting seed bank (viable for longer than one year), or seedbank unknown (0)
2. small – species relies on small, annually produced seed bank (1)

6. Post-fire ephemeral

Some species are short lived and are only present in the landscape for ten or less years following fire. Their seed then remains in the soil before regenerating after the next fire. Such species are often targeted for harvesting in the early post-fire succession because they tend to be the first species to regenerate. These species tend to have a relatively small stature which also increases their vulnerability to harvesting. Therefore, harvesting of short-lived plants is likely to reduce seed banks to unacceptably low levels:

1. plants only present in the first ten years after fire (1)
2. plants long lived, and present for longer than ten years after fire (0)

7. Serotiny

Species can be defined as serotinous and non-serotinous. Many proteoid species store their seeds on the canopy in fire resistant cones (serotiny) which open after scorching by fire (Bond 1985). Thus, the seeds accumulate on the plant from year to year, and the entire seed bank is stored on the plant until fire stimulates release and subsequent mass germination. The removal of such seed by harvesting reduces post-fire recruitment levels.

Serotinous species vary in the degree to which they hold their seeds in the canopy (Bond 1985, Mustart and Cowling, 1992). Weakly serotinous species release most seed from cones older than two years. More strongly serotinous species hold their seeds in cones for four to five years. Seed bank depletion will tend to be more severe in weakly serotinous species, as harvesting of the current year's seed results in a high proportion of the total seed bank on the plant being lost (Mustart and Cowling, 1992). In strongly serotinous species removal of the current year's crop has less impact on total seed reserves. Most plants that are non-serotinous have another mechanism of surviving in the soil which often involves a plant-animal interaction. For example, myrmechocory where seeds are dispersed but not eaten by ants (Bond & Slingsby 1983). A negative impact on an ant population might correspond with a reduction in population sizes in taxa that are buried by the ant, and *vice versa*.

Harvesting directly impacts serotinous and non-serotinous species (e.g. myrmecochorous species and those with soil stored seed banks). Myrmecochorous species, or other seeds that are buried by animals in the *fynbos* are vulnerable to harvesting because of the dependence on the presence of the species which contributes to seed bank survival and post-fire recruitment. However, at this stage we have insufficient data on whether these different guilds are impacted differently by the same levels of harvesting. For this reason, both non-serotinous and weakly serotinous categories have been allocated the same impact and are rated as (1). Strongly serotinous species may be less at risk from harvesting, as canopy stored seed may be less vulnerable to predation or severe fires, and seed stores can accumulate more readily. Further research is required to better understand the dynamics at play in these cases. Such research may require refinement of the grading currently applied:

1. Non-serotinous species – species without canopy-stored seed (1)
2. Weakly serotinous species – species with canopy-stored seed for short periods (1)
3. Strongly serotinous species – species with canopy-stored seed for longer periods (0)

Results

Fifty-two species scored nine, ten or eleven, and are therefore designated as 'no-go' species for harvesting (see Figure 3 below). Thus, more than one third of all the species assessed in this exercise are at significant risk, with the potential to become locally extinct through harvesting. This highlights the precarious state of the *fynbos* biome as a whole. The pressures that species are facing on the Agulhas Plain are emphasized by the fact that many of the species listed as no-go under the Vulnerability Index are not considered to be as threatened across the CFR as a whole, as indicated by their Red List categorization. Twenty-nine species scored seven or eight and should be carefully monitored, most especially the thirteen which are known to be currently harvested. If there is any indication of declining populations in this group of species, especially those with an Index score of eight, they may also need to be classified as no-go species. A further twenty-two species (of which fifteen are harvested) scored five or six. These are vulnerable species and should also be monitored. Species that scored two, three or four can be considered the least vulnerable to harvesting. Sustainable harvesting should be easily achieved with such species. Over-harvesting is likely to be a significant factor in cases where population declines are recorded in species that have a low Vulnerability Index score.

[Insert Table 1 near here]

[Insert Table 2 near here]

Below are some selected examples that illustrate the value of the Vulnerability Index in terms of a decision-making tool for management. All of these species were harvested prior to the development of the Vulnerability Index.

***Erica irregularis* (Red List status – Endangered)**

Erica irregularis has a very restricted distribution on coastal limestone flats and hills on alkaline soils between the villages of Stanford and Gansbaai on the Agulhas Plain (Mustart et al, 1997: Oliver and Oliver, 2002; Schumann and Kirsten, 1992). While its total geographic extent covers an area of less than $10km^2$, it is very common within its distribution range, turning the hills bright pink when it flowers in the winter. Easily confused with other pink flowering *Ericas* in the region, it was intensively harvested prior to the development of the Vulnerability Index and its introduction into the permitting system of CapeNature. Owing to its very localized distribution, *Erica irregularis* scores high for geographic range and abundance and has an overall VI of 10, which according to our categories places it in the 'no-go' group for harvesting. Since the introduction of the Vulnerability Index into the permitting system this species can no longer be harvested legally, thereby significantly improving the long term conservation prospects of this rare, local endemic.

***Leucadendron platyspermum* (vulnerable) and *Protea compacta* (near threatened)**

Both *Leucadendron platyspermum* and *Protea compacta* are commercially sought after species that are threatened by intensive flower harvesting. Owing to their popularity as cut flowers, both species have been widely sown into areas where they did not naturally grow on the Agulhas Plain. Thus, while they both have a relatively narrow natural distribution, they are now found over a far wider area through broadcast sowing of seed following fire. Both are serotinous species retaining their seed on the plant until fire.

Leucadendron platyspermum has a Red List status of vulnerable (Raimondo et al, 2009). Its status is complicated by the great increase in the population size over the past 50 years due to planting in orchards and sowing into bush cut and burnt veld. Up to the 1980s only female cones were harvested and this led to post-fire population collapses. There was also heavy pressure on natural populations where female cones were harvested to provide seeds for orchards. This situation was reversed in the last few decades as market trends resulted in the male cones being highly sought after. If market trends were to change again then the populations (both natural and planted) could once again come under heavy threat (Raimondo et al, 2009). Another potential threat that is difficult to evaluate is the management practice of thinning out females to favour males. The species has a VI of 7, making it a priority to monitor. Future trends in the flower industry could well influence its long term conservation status, and it is clearly an important species for ongoing monitoring.

Protea compacta has a Red List status of near threatened as a result of a 35% reduction of the range and 23% habitat loss due to urban expansion, agriculture and alien plant invasion in the past 60 years (Raimondo et al. 2009. However,, like *Leucadendron platyspermum* while there has been a significant reduction in the species natural distribution, it has been widely sown for commercial use, thus increasing its distribution range and abundance. It is a popular wild flower that has been known to hybridise with *P. compacta* cultivars. It has a VI of 7 and requires careful monitoring going forward.

Brunia laevis (Red List status – Locally common)

This species is currently one of the most sought after naturally growing harvested species on the Agulhas Plain. It is a resprouting species that can survive fairly high levels of harvesting. A recent study showed that unlike other sprouting species, *Brunia laevis* was able to survive even 100% harvesting over a number of years (Privett et al. 2014). However, the increasing mortality with time relative to lower harvesting rates in the study suggested that harvesting at 100% over the longer term (>5 years) is not sustainable. This species scored a VI rating of 6, which suggests it should be a priority for monitoring. It would appear that the species is quite resilient to heavy harvesting over the short-term. However, given the high demand (and that it is almost exclusively harvested from limited wild populations), this species could indeed become threatened by continual harvesting over the long term. Anecdotal evidence, which is reinforced by rapidly increasing prices suggesting supply problems, indicates that *Brunia laevis* in indeed coming under pressure (Bek and O'Grady 2018).

Staavia radiata (Red List status – Locally common)

Staavia radiata is also a sprouting species that is commonly used as a foliage 'filler' in flower bouquets. Despite the findings of Privett et al. (2014), that it is more susceptible to intense harvesting than *Brunia laevis,* it scored a lower 3 on the VI compared *to Brunia laevis.* This is as a result of its significantly wider distribution, greater abundance and soil-stored seed bank. When compared to *Brunia laevis* it is more resilient to moderate harvesting levels.

Leucadendron xanthoconus (Red List status – locally common)

This is a very widespread and common species that occurs in dense stands on well-drained sandstone soils. It has a natural distribution stretching from the Cape Peninsula in the west to the Potberg in the East. As a result of its wide distribution and dense stands, as well as its prolific regeneration following fires, its VI is just 2. However, even in *Leucadendron xanthoconus*, heavy harvesting can result in population crashes in certain areas across its range. Serotinous species rely on canopy stored seed for recruitment after fire. If too many cones are removed as a result of flower harvesting there will be insufficient seed for regeneration after fire and populations will decline. The rule of thumb for these serotinous *Proteaceae* is to remove no more than 50% of all cones or flower heads over a season (Mustart and Cowling, 1992).

Other biological characteristics with the potential to be used in the Index

The above characteristics are sufficient for identifying the extent of vulnerability of the more sensitive species. Below are some descriptions of five other characteristics that could be used in future iterations of the Vulnerability Index. In the meantime, the characteristics below may be useful to decide on borderline species, or species of special concern whose overall Vulnerability Index score may not be high.

1. Seed dispersal distances

Species that are able to disperse their seeds over large distances are more resilient to local extinctions than species with limited seed dispersal distances. From a harvesting perspective, seed from geographically distant populations could restock populations of wind-dispersed species that are over-harvested. Those with short dispersal distances are more likely to be permanently impacted. The inclusion of serotiny within the Index has largely accommodated this characteristic since serotinous species are wind-dispersed:

(i) long distance (wind dispersal) (0)
(ii) short distance (myrmecochorous or ballistic dispersal) (1)

2. Habitat or vegetation type

Certain habitats may be extremely specialised or rare, or the habitat may be home to a large number of rare or endangered species that should afford the species a higher score on the Vulnerability Index. Species restricted to wetlands and seepage areas (e.g. *Leucadendron* *linifolium* and *Leucadendron laxum*) are a good example, as are species restricted to the highly fragmented and critically endangered Elim ferricrete fynbos patches within agricultural lands on the Agulhas Plain (e.g. *Leucadendron modestum* and *Leucadendron elimense*). In general, the geographic range and abundance characteristics provide some accommodation for these factors in the Index:

(i) generalised or various habitats (0)
(ii) special habitat (1)

3. Pollination syndrome

Plants that are pollinated by wind, as opposed to insect or animal pollination, are less vulnerable to harvesting. Animal pollinated plants are more prone to not being pollinated due to a collapse in the pollinator's population for some reason. This collapse may be induced by harvesting, which reduces the resources that the pollinator may be dependent on for survival or reproduction. Wind-pollinated plants are resilient to this:

(i) wind pollinated (0)
(ii) animal pollinated (1)

4. Susceptibility to plant diseases or fungal attack

Some plants may be more prone to disease or fungal attack as a result of harvesting. More research is required to support the inclusion of this potentially important characteristic:

(i) little or no threat from disease or fungi (0)
(ii) high risk of disease or fungal attack (1)

5. Sprouters that struggle to regenerate

Some sprouters have slow-growing seedlings, and seedling establishment is sometimes rare or absent. Although such sprouting plants are thought to be quite resilient and long-lived, they are bound to have a life-span. Some paleoendemic sprouters may even be examples of the 'living dead' (Swart 2019). The climate or some other variable is no longer suitable for their regeneration, and because of this they have lost the ability to adapt and evolve to a changing environment. Some species may be quite common and widespread, but closer study of their life history could reveal that some or all populations are on the verge of extinction. Sprouters are also often few in numbers relative to re-seeders, which tend to develop denser populations.

Mathematical models of various life history strategies show that changes in recruitment levels in the order of magnitude likely to result even from high levels of harvesting in these species (e.g. almost total loss of seed bank) has negligible impact on population dynamics, but changing adult mortality has a dramatic impact.

Accordingly, sprouters that are likely to be killed by harvesting and have low recruitment should receive a score of 2 or higher. Unfortunately, there is not enough information available on this characteristic to include it in the Index yet:

(i) sprouters that struggle to regenerate (1)
(ii) sprouters that regenerate readily (0)
(iii) sprouters that get killed by harvesting and struggle to regenerate (2)

Discussion

Distribution range and abundance strongly influence the outcome within the Index. Some of the other characteristics may be more significant than is currently thought, therefore it is important that there is ongoing research on the impacts of harvesting on seed reserves and regeneration. Species that have a low Vulnerability Index score could be at risk if declines in population go unnoticed. Therefore, it is vital that all industry and conservation stakeholders remain vigilant.

It is important to remember that ecosystems are deeply interconnected and inter-related systems. Therefore, changes within the population of a single species can have marked impacts throughout the ecosystem. For example, the reduced abundance of common and widespread plant species can be a problem because these often support critical ecosystem functions, without which all species become threatened. For example, animals which pollinate or disperse seed of a wide variety of plant species may be dependent on only one or a few common species for the bulk of their diet. Without the key resources provided by healthy populations of these common plant species, the animals may disappear, which could lead to the loss of pollination or dispersal for a large variety of other plant species.

Fire also plays a major role across *fynbos* landscapes (Pooley 2012). Common widespread species can suffer significant temporal declines following fires, resulting in considerable pressure on remaining stock. This can influence the vulnerability to harvesting of even common, widespread species. Thus, a decline in one common species could concur with, and actually cause, the decline of other species. On the contrary, a decline in one species might accommodate other species more readily by reducing competition for space in which to grow.

Over harvesting of one species might favor recruitment and establishment of a co-occurring competitor (Anderson 1996), with subsequent impact on the competitive dynamics between species following future fires. Such interactions are difficult to detect, as fynbos is naturally a temporally dynamic ecosystem (Privett et al. 2001) where species presence and abundance is generally stable at the broader landscape scale but highly unstable at the local scale (Thuiller et al. 2007). As such monitoring of harvested species requires a landscape-level resource base-assessment approach (Bailey et al. 2007) if impact of harvesting on common species is to be determined. Thus, there should be no complacency with regard to species with low Vulnerability Index scores. Declines in these populations are not acceptable, rather the aim should be to implement conservation measures including farm wide resource base assessments which will enable proper monitoring of the impact of harvesting on species with low Vulnerability Index scores.

As noted above, six species of *Erica* are listed as 'no go' for harvesting. However, eliminating the picking of these sub-species is not straightforward. Differentiating between closely related *Ericas* is difficult, and the common name 'Erica Pink' is frequently used in the harvesting industry, which does not allow for differentiation between species of pink flowering *Ericas.* The most feasible way of avoiding harvesting endangered *Ericas* is by making the habitat or areas in which they grow 'no go' areas for harvesting of *Ericas*. Legislation states that all harvested species should be accurately recorded to the species level, thus the practice of using generic names on licenses and delivery notes should be phased out.

It was also interesting to note that rare species tend not to be harvested, and are, in a sense, protected by their rarity, while common or more abundant species tend to be targeted due to the high volumes required by retailers. However, high offtake levels over prolonged periods of time, especially if negative exogenous events such as droughts occur, could trigger rapid changes in overall populations. Harvesting businesses requires a greater volume of product due to marginal increases in prices for wild *fynbos* products in order to sustain these businesses (Bek and O'Grady 2018). Thus, there is a need for constant monitoring of all species.

The development of the Vulnerability Index has drawn attention to a practice referred to as ‘broadcast sowing’. This refers to the deliberate sowing of seed in natural landscapes after fire, with a view to expanding natural species distribution and its densification for economic benefit (Treurnicht 2010). The practice is controversial, as conservationists view it as a form of unregulated cultivation, whereas landowners and industry members regard it as species augmentation within the natural landscape. These farming practices ultimately result in distorted competitive interactions and disturbance regimes and reduced the ecological integrity (Treurnicht 2010). *Protea Compacta* and *Leucodendron Platyspermum* are two species that regularly appear in dense stands in the landscape as a result of this practice (Treurnicht 2010). Such stands of broadcast sown species pose a challenge for the implementation of the Vulnerability Index as they are not natural. A better understanding of the scope, extent and impact of this practice on the natural landscape is required. It is recommended that such information be collected as part of the permitting system.

Therefore, the question has to be asked as to whether the Vulnerability Index should apply in these cases? Quite simply, does it matter if ‘unnaturally’ occurring stands are harvested? Indeed, might it be good practice to harvest them back to allow other species space to compete? An alternative would be that in cases where augmentation is proven, species could potentially be harvested at a higher intensity than prescribed under the sustainable harvesting guidelines. Higher harvesting levels might reduce the induced or enhanced population, thus allowing natural species to compete, retaining natural species diversity on the property. It should be noted that CapeNature’s ordinance does not offer a clear ruling on the status of broadcast sowing as a practice. It is therefore clear that conservation objectives would be best served by the implementation of a research programme across the Agulhas Plain which identifies the prevalence and impacts of broadcast sowing leading to clear guidance within CapeNature’s ordinance.

Finally, the potential impact of climate change on fynbos species abundance and distribution and hence harvesting impact should not be underestimated. Recent long-term (44 year) temporal comparative studies in fynbos have found evidence of diversity loss driven by the interaction between fire and intensifying periods of hot and dry weather in the CFR (Slingsby et al. 2017). According to this study the exacerbation of post-fire mortality by increasingly severe weather extremes is likely to drive major shifts in the composition, structure, and function of fire-prone ecosystems subject to severe summer droughts and temperature extremes. This is cause for concern given the potential negative impact of flower harvesting on seed availability for post-fire regeneration, further supporting a conservative approach to the regulation of the fynbos wildflower industry across the CFR.

Conclusion

The Vulnerability Index is a pioneering initiative which draws upon existing botanical knowledge to develop locally nuanced guidance as to the vulnerability of fynbos species to harvesting. As such, the Vulnerability Index is an important contribution to conservation in South Africa, whilst it will also support the long-term sustainability of the wildflower harvesting industry (Van Deventer et al 2016). The formal incorporation of the Vulnerability Index into CapeNature's permitting process is an important step forward, which will provide their staff with a further mechanism for making informed decisions concerning permitting allocations on the Agulhas Plain (Lombard et al 1997) Furthermore, the principles embodied within the Vulnerability Index set important precedents for regulation of other forms of wild harvesting, both within the CFR and in other regions of the world. For example, the Vulnerability Index and its methodology also have potential to be applied for the licensing of harvesting for medicinal purpose, horticultural collections and ornamental purposes in other environments (Petersen 2014). Given the pressures being imposed upon wild landscapes by land use change and climate variability it is vital that sensitive and scientifically informed monitoring strategies are enacted.

The process of developing and implementing the Vulnerability Index has stimulated debate about the ecological characteristics of *fynbos* species, the ecosystems within which they exist and their responses to being harvested. Many new areas for research have been identified, and it is crucial that efforts are invested into ensuring that a coordinated research strategy is implemented between universities, conservation organisations and industry bodies. We would strongly recommend that steps are taken urgently to implement such a research strategy, which will enable the Vulnerability Index to be refined and rolled out into other regions of the CFR which are undergoing harvesting. Furthermore, we urge that the principles underpinning the Vulnerability Index are institutionalized within the regulatory spaces of conservation within South Africa and are disseminated broadly within the field of environmental management across the globe.

References

Bailey R, Euston-Brown K, and Privett S. 2007. "Resource base assessment of wild fynbos plants on Waterford Farm, Agulhas Plain: A pilot study". Bredasdorp: Flower Valley Conservation Trust.

Bek, D., Binns, T., and Nel, E. 2013. "Wildflower harvesting on South Africa's Agulhas Plain: a mechanism for achieving sustainable Local Economic Development?" *Sustainable Development* 21 (5): 281-293. doi: 10.1002/sd.499.

Bek, D., Binns, T., Hughes, A., McEwan, C., and Blokker, T. 2017. "A High Road to Sustainability? Wildflower Harvesting, Ethical Trade and Social Upgrading in South Africa's Western Cape." *Journal of Agrarian Change*. 17 (3): 459-479. doi: 10.1111/joac.12149.

Bek, D. and O'Grady, K. 2018. "The Scale, Structure and Sustainability of the Wild Fynbos Harvesting Supply Chain in the Cape Floral Kingdom." *Report for the Table Mountain Fund Cape Town, South Africa.* http://www.flowervalley.org.za/wp-content/uploads/2018/12/TMF-Research-Report-Final.16nov2018.pdf. Accessed March 21st 2018.

Binns, J.A., Illgner, P.M. and Nel, E.L. 2001. "Water shortage, deforestation: South Africa's Working for Water programme." *Land Degradation and Development*.12: 341-355. doi: 10.1002/ldr.455.

Bond, W.J. and Slingsby, P. 1983. Seed dispersal by ants in shrublands of the Cape Province and its evolutionary implications. S. Afr. J. Sci. 79: 231-233.

Bond W.J. 1985. Canopy-stored seed reserves (serotiny) in Cape Proteaceae. South African Journal of Botany. 51: 181-186.

CapeFloraSA 2016. "Joint Marketing Forum Briefing: SA Exports and Estimates." http://www.capeflorasa.co.za/wp-content/uploads/2013/02/JMF-24-Feb-2016-Exports.pdf. Accessed August 16th 2016.

CapeNature 2016. "World Heritage Sites." http://www.capenature.co.za/care-for-nature/conservation-in-action/landscape-scale-conservation/world-heritage-sites/. Accessed August 16th 2016.

Child, B. 2010. "Independent Terminal Evaluation of the UNDP-GEF CAPE Agulhas Biodiversity Initiative (ABI)." https://www.thegef.org/sites/default/files/project_documents/2006_1055_BD_South%2520Africa_TE.pdf. Accessed 19 March 2019.

Cowling, B. and Holmes, P.M. 1992. "Endemism and speciation in a lowland flora from the Cape Floristic Region." *Biological Journal*. 47 (4): 367-383. doi: 10.1111/j.1095-8312.1992.tb00675.x.

Cowling R, Richardson D. 1995. "Fynbos: South Africa's unique floral kingdom." Fernwood Press: Cape Town.

Davis, G.W. 1992. “Commercial Exploitation of Natural Vegetation: An Exploratory Model for Management of the Wildflower Industry in the fynbos Biome of the Cape, South Africa.” *Journal of Environmental Management*. 35: 13–29.

DTI-RSA 2016. “Flora Export Statistics.” http://tradestats.thedti.gov.za/TableViewer/tableView.aspx. Accessed August 16th 2016.

FVCT (Flower Valley Conservation Trust) 2012. “Agulhas Plain Fynbos Monitoring Project: Grant Proposal to Global Environment Facility.” Unpublished document.

Goldblatt P. and Manning J. 2000. “Cape Plants: A Conspectus of the Cape Flora of South Africa.” *Strelitzia.* 9: 743. South African National Biodiversity Institute: Pretoria.

Golding J.S. (ed.) 2002. “Southern African Plant Red Data Lists. Southern African Botanical Diversity Network, Report 14.”

GSA (Government of South Africa) 2005. “The National Biodiversity Strategy and Action Plan.” Pretoria.

Heydenrych, B. J. 1999. *An investigation of land-use practices on the Agulhas Plain (South Africa), with emphasis on socio-economic and conservation issues*. Unpublished M.Sc. thesis. Cape Town: University of Cape Town.

Hilton-Taylor, C. 1996. “Red data list of Southern African Plants.” *Strelitzia.* 4. South African National Biodiversity Institute: Pretoria.

Laubscher C.P, Ndakidemi P.A., Bayat M.S., and Slabbert A. 2009. “Conservation and Propagation of endangered Proteaceae on the Agulhas Plain for sustainable ecotourism development.” *Scientific Research and Essays.* 4 (5): 374–380.

Lombard A.T. Cowling R.M., Pressey R.L. and Mustart P.J. 1997. “Reserve Selection in a Species-Rich and Fragmented Landscape on the Agulhas Plain, South Africa.” *Conservation Biology*. 11 (5): 1101-1116.

Manning J and Goldblatt P. 2012. “Plants of the Greater Cape Floristic Region. The Core Cape Flora.” *Strelitzia. 29*. South African National Biodiversity Institute: Pretoria.

Marais K. 2012. Postfire regeneration of mountain fynbos by resprouting: A comparison of species with different life history types. MSc Conservation ecology, Stellenbosch University.

Maze, K.E., Bond, W.J., 1996. Are Protea populations seed limited? Implications for wildflower harvesting in Cape fynbos. *Australian Journal of Ecology* 21, 96–105.

Mustart, P.J. and Cowling, R.M. 1991. “Seed germination of four serotinous Agulhas Plain Proteaceae.” *South African Journal of Botany*. 57: 310-313.

Mustart, P.J. and Cowling, R.M. 1992. “Impact of flower and cone harvesting on seed banks and seed set of serotinous Agulhas Proteaceae.*” South African Journal of Botany* 58: 337-342.

Mustart, P.J., Cowling, R.M. and Albertyn, J. 1997. *Southern Overberg. South African Wild Flower Guide 8.* Botanical Society of South Africa: Cape Town.

Oliver E.G.H. and Oliver I.M. 2002. "The genus Erica (*Ericaceae*) in southern Africa: taxonomic notes 1." *Bothalia*, 32 1: 37-61.

Petersen, L. 2014. "Cape Town's Trade in Wild Medicines: Ecological Threat or Essential Liveliohood Resource?" http://www.econ3x3.org/article/cape-town%E2%80%99s-trade-wild-medicines-ecological-threat-or-essential-livelihood-resource. Accessed March 21st 2019.

Pooley, S. 2012. Recovering the Lost History of Fire in South Africa's Fynbos', *Environmental History*. 17, (1): 55-83.

Privett S.D.J, Cowling R.M., and Taylor H.C. 200. Thirty years of change in the fynbos vegetation of the Cape of Good Hope Nature Reserve, South Africa. Bothalia 31,1: 99-115

Privett S.D.J, Heydenrych B, Cowling R. 2002. "Putting Biodiversity to Business on the Agulhas Plain". Pp.101-116 in *Mainstreaming Biodiversity in Development: Case studies from South Africa,* edited by Pierce S.M., Cowling R.M., Sandwith T. and MacKinnon K. The World Bank Environment Department: Washington DC.

Privett S.D.J. and Gaertner M. 2012. Sustainable harvesting of fynbos species: resources, impact and best practice. Agulhas Biodiversity Initiative report.

Privett S.D.J., Krug, R.M., Forbes, G. and Gaertner M. 2014. "Wild flower harvesting on the Agulhas Plain, South Africa: Impact of harvesting intensity under a simulated commercial harvesting regime for two re-seeding and two re-sprouting fynbos species." *South African Journal of Botany*, 94: 270-275. http://doi.org/10.1016/j.sajb.2014.06.015.

Privett S D J, Dames Rand Louw N 2018. "An updated plant species list for the Agulhas plain region of South Africa". Agulhas Biodiversity Initiative Working Paper.

Raimondo D., Von Staden L., Foden W., Victor J.E., Helme N.A., Turner R.C., Kamundi D.A. and Manyama P.A. 2009. "Red List of South African plants." *Strelitzia*. 25. South African National Biodiversity Institute: Pretoria.

Rebelo, T. 1995. *A field guide to the Proteas of Southern Africa*. Cape Town: Fernwood Press.

SANBI (South African National Biodiversity Institute) 2017. "Red List of South African Plants. Cape Town." http://redlist.sanbi.org/stats.php/genera.php?generalike=o. Accessed March 1st 2017.

Schumann D. and Kirsten G. 1992. *Ericas of South Africa*. Cape Town: Fernwood Press.

Slingsby JA, Merow C, Aiello-Lammensd A, Allsopp N, Hallf S, Mollmannd HK, Turner R, Wilson AM & Silander Jr. JA 2017. *Intensifying postfire weather and biological invasion drive species loss in a Mediterranean-type biodiversity hotspot.* PNAS, vol. 114,| no. 18 pp. 4697–4702

Swart C. 2019. *The conservation, ecology, and distribution of the Critically Endangered Encephalartos latifrons.* Unpublished PHd thesis, Rhodes University.

Thuiller W, Slingsby JA, Privett SDJ, Cowling RM. 2007. *Stochastic species turnover and stable coexistence in a species-rich, fire-prone plant community.* PLoS ONE 2: e938

Treurnicht, M. 2010. *Wildflower farming on the Agulhas Plain: fynbos management and conservation*. Unpublished M.Sc. thesis. Stellenbosch; University of Stellenbosch.

Turpie J.K. 2004. "The role of resource economics in the control of invasive alien plants in South Africa." *Ecological Economics.* 46: 199–216.

UNDP (United Nations Development Programme) 2003. *Agulhas Biodiversity Initiative. Global Environment Facility Project document.* Cape Action for People and Environment: Cape Town.

Van Deventer, G., Bek, D. and Nakwa, M. 2015. *Revising the key points of the Sustainable Harvesting Code of Practice*. Audio-visual resource: https://www.youtube.com/watch?v=lcJVQXuN6vM&index=1&list=PLHdurNYLS8rEpRiveDsDLMXerMNmQiRfh. Accessed 20th April 2018.

Van Deventer, G., Bek, D. and Ashwell, A. 2016. *The Field Guide for Wildflower Harvesting.* doi: 10.13140/RG.2.1.4654.4248.
